STATISTICAL PROFILE OF ACCIDENTS AT SMALL UNDERGROUND COAL MINES

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ABSTRACT

The U.S. Bureau of Mines prepared this paper to provide statistical information on accidents, production, and employment at small U.S. underground coal mines. Mines are categorized according to size as follows: fewer than 20 employees, 20 to 50 employees, 50 to 100 employees, and more than 100 employees. For each size category, statistics are presented showing the following: (1) the number of mines and the States in which they are located; (2) changes in employment, production, and rates of fatal and permanently disabling accidents between two periods (1978-80 and 1989-91); and (3) rates of coal production and rates of various types of serious accidents. The five States with the largest number of small underground coal mines are Kentucky, West Virginia, Virginia, Pennsylvania, and Tennessee. Statistics are presented to show how various sizes of mines in these 5 States compare with one another in terms of safety and productivity. Statistics are also presented showing how miners who are injured while working at mines of various sizes compare in terms of age and experience. Several propositions about why small mines have higher fatality rates are reviewed.

INTRODUCTION

The National Academy of Sciences (NAS) published studies (*5-6*)[3] in 1982 and 1983 examining the relationship between the size of underground coal mines and the rate of fatal accidents. It found that during the period 1978-80, the fatality rate for mines with 50 or fewer employees (0.14) was about 3 times that of mines with over 250 employees (0.05), and almost twice that of mines with 51 to 250 employees (0.08). The researchers note:

> This strong correlation between mine size and fatality rates was evident in all the data from the [U.S.] Mine Safety and Health Administration (MSHA) we examined dating back to 1969. Furthermore, the association was not explainable by company ownership, union status, seam thickness, or any of the other factors we examined.

More recent data from MSHA indicate that the discrepancy between fatality rates at small versus large mines has grown even more extreme since the NAS study was performed. Tisdale (*8*) writes:

> In 1992, small underground coal mines, with fewer than 20 employees, had a fatal incidence rate of about 6 times that of larger mines, and those with more than 20 but fewer than 50 employees had a rate about 4 times that of larger mines.

The NAS researchers analyzed data on accidents at underground coal mines during the late 1970's to try to establish which of several factors might be responsible for the fact that fatality rates are so much higher at small mines. Their findings are reviewed briefly as follows.

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Exposure to Face Areas of the Mine.—One potential explanation of the association between mine size and fatality rates is that in large mines there are proportionally more workers away from the working face and therefore at reduced risk for a fatality. If this were true, then smaller mines would have larger fatality rates even though the risks for miners at the working face were the same as in larger mines. The NAS researchers allowed for this possibility in their analyses (*6*, pp. 91-93), but found that, at best, it could explain only a part of the strong association between mine size and fatality rates.

Seam Thickness.—The NAS researchers investigated the impact that seam height might have on explaining the differences between fatality rates at small versus large mines. They note that, in general, smaller mines have thinner coal seams than larger mines. However, they were unable to find any clear relationship between seam thickness and the fatality rate in small mines. In contrast, within each thickness category the fatality rate tends to decline with increasing mine size. Therefore, the authors concluded that the association between mine size and fatality rate is not due to differences between small and large mines with respect to seam thickness. However, about 78% of mines with 20 or fewer employees and 59% of mines with 21 to 50 employees failed to report seam heights for the period being studied (1975-80). Such a large amount of missing data precluded doing a thorough analysis of seam height relative to mine size. Unfortunately, it is impossible to determine the extent to which this lack of data may have influenced the results that were reported.

Duration of Active Operation.—The NAS (*5*) researchers note that there are striking differences between small and large mines with respect to the length of time they remain open. They note that smaller mines operate for shorter periods of time and more intermittently than larger mines, which tend to operate more or less continuously. The majority (57%) of small mines in their sample were active for 18 months or less during 1975-80, compared with only 4% of larger mines.

The NAS researchers hypothesized that part of the difference between fatality rates at small versus large mines may reflect a "learning curve" phenomenon. The reasoning behind this notion is that the risk of a fatality is greatest shortly after a mine first opens and thereafter declines—i.e., the risk of fatalities decreases over time. Although this notion appears plausible, the NAS researchers could not find sufficient evidence from their data to support it.

The NAS findings strongly suggest that various factors that sounded like plausible explanations for the difference between fatality rates at small versus large mines are actually NOT capable of accounting for the large differences that exist. Unfortunately, researchers have yet to establish what the factors are that can account for the large disparity. The NAS (*5*) researchers speculate that the following factors may have been at least partly responsible for the disparity:

> On the basis of our examination of fatality reports, discussions with operators of small underground coal mines, and the experience of the Committee's three mining engineers and geologist with small mine operations, we believe the following factors exacerbate the safety problem in small mines:
>
> 1) The mining equipment in small mines is of lower quality, sometimes secondhand, and less well maintained.
> 2) The physical condition of employees in small mines is less favorable to safety—small operators sometimes employ workers that large companies will not accept.
> 3) The financial resources available to operators of small mines are limited. Hence many of these operators are not able to support the more extensive safety programs employed by some major coal companies (using safety engineers and technicians).

Statistics on rates of fatalities and permanently disabling injuries strongly suggest that small mine operators face some unique obstacles to maintaining their employees' safety. The U.S. Bureau of Mines (USBM) prepared this paper to (1) update the NAS accident statistics, (2) identify changes that have occurred since 1980, and (3) enumerate the propositions that have been set forth to try to account for the differences in the safety performance of small versus large mines. The information this paper provides may be useful in arriving at causal explanations and successful interventions aimed at improving miners' safety—especially at small underground coal mines.

METHODS

The data presented here are drawn from MSHA's database of mining production, employment, and accidents for the entire population of U.S. underground coal mines. MSHA gathers these data in accordance with Part 30 of the U.S. Code of Federal Regulations. To collect this information, MSHA requires mines to submit a form (7000-1) that describes each "reportable" accident. Also, each working mine must submit quarterly information about their operations, including production, employee-hours, and mine characteristics on another standard form

(7000-2). The USBM has access to computerized copies of this information for all mine operators from 1975 through 1991. The USBM does not have access to computerized data about independent contractors. Independent contractor employees have become a more significant part of the mining work force in the past decade. They may perform a wide variety of support functions for mine operators, such as hauling coal or constructing various facilities on mine property. Consequently, the numbers presented here will be slightly smaller than analyses that include independent contractors. Also, reporting requirements for contractors are somewhat different from those for operators, so the data are not readily comparable.

The analyses presented here primarily cover the years 1989 through 1991. At this writing, the 1991 data are the most recent available in the USBM's copy of the MSHA database. A limitation of the MSHA data is that not all of the information on the reporting forms is complete for all the mines in the database. For instance, information on employment, production, and other variables is sometimes missing. A total of 2,187 mines met the selection criteria of reporting nonzero underground production, or reporting a fatality during at least 1 of the 3 years studied. (That is, mines that reported zero coal production were included in the analyses only if a fatality had occurred at that location.)

The injury data analyses will focus on three types of injuries: (1) fatalities (MSHA "Degree of Injury" code 1), (2) permanently disabling injuries (MSHA "Degree of Injury" code 2), and (3) lost-time injuries that caused the employee to miss more than 20 days of work (referred to as serious injuries).

Throughout the tables of statistics presented in this paper, mines have been stratified according to their size. Mines were usually put into one of the following four size categories based on the average number of employees at that operation: 1 to 20, 21 to 50, 51 to 100, and more than 100. Both the number of employees and the number of employee-hours included people who worked (1) underground, (2) at the surface of underground mines (except office workers), and (3) in preparation plants at underground mines. The size of each mine was usually determined by averaging the annual number of employees reported by the mine for 1989, 1990, and 1991. However, there were a couple of exceptions to this procedure: (1) All data pertaining to office workers were excluded from the analyses because these workers are not normally exposed to the types of hazards that other mine employees face; (2) mines where a fatality had occurred were placed into the mine size category that corresponded to the average number of employees the mine reported *for the year of the fatality* as opposed to using the 3-year average. This was done to accurately characterize what mines were like at the time the fatal accident occurred and also to be consistent with MSHA's statistics for the number of fatalities occurring in mines of a particular size category.

The NAS researchers considered mines of 50 or fewer employees to be "small" mines. This paper follows the same convention—the term "small mines" always refers to mines of 50 or fewer employees. However, close to half of U.S. underground coal mines employ 20 or fewer people. Because so many mines are in this category, statistics are always reported for each of two separate categories of small mines: mines of 20 or fewer employees and mines that employ between 20 and 50. Throughout this paper, mines that employ 20 or fewer people are always referred to as "very small" mines, and mines that employ more than 50 people are considered to be "large" mines.

FINDINGS

The findings are organized into 10 tables of statistics. Each table is discussed below, beginning with a look at the number of mines in each size category that are located in each State.

LOCATION OF MINES

Table 1 breaks down the total number of underground coal mines that reported any coal production during 1989-91 by State and mine size. Over half of the underground coal mines in operation during this time period were concentrated in the States of Kentucky and West Virginia, with 38.6% and 28.4% of the total number of mines, respectively. Virginia accounted for 15.4% of the mines, followed by Pennsylvania with 8.3%. Similarly, the majority of very small mines are concentrated in these States as well. Of the 1,217 mines in this size category, 507 (41.7%) are located in Kentucky, 298 (24.5%) in West Virginia, 206 in Virginia, 120 in Pennsylvania, and 53 in Tennessee.

UNDERGROUND COAL PRODUCTION

The total amount of coal produced from underground mines during 1989-91 is broken down by State and mine size in table 2. West Virginia mines produced 29.1% of the underground coal mined in the United States, followed by Kentucky mines with 24.4%. Other major producers of underground coal include Illinois (10.5%), Pennsylvania (10.1%), and Virginia (8.9%). Most of this production (60.3%) was from mines employing over 100 employees. Very small mines accounted for 8.5% of total underground coal production, and mines employing from 21 to 50

employees accounted for 20.2%. Of the coal produced by very small mines, 40% came from Kentucky, 30% from West Virginia, 20% from Virginia, 3.8% from Pennsylvania, and 2.7% from Tennessee.

Table 1.—Number of underground coal mines stratified by State and mine size (number of employees) in 1989-91

State	Number of employees					
	1 to 20	21 to 50	51 to 100	Over 100	Total	% of U.S. total
Alabama	6	1	1	9	17	0.8
Colorado	6	3	3	5	17	0.8
Illinois	2	4	2	23	31	1.4
Kentucky	507	262	41	34	844	38.6
Ohio	8	3	1	7	19	0.9
Pennsylvania	120	23	16	23	182	8.3
Tennessee	53	23	3	1	80	3.7
Utah	5	2	7	8	22	1.0
Virginia	206	102	20	9	337	15.4
West Virginia	298	256	27	41	622	28.4
Other[1]	6	4	4	2	16	0.7
U.S. total	1,217	683	125	162	2,187	NAp
% of U.S. total	55.6	31.2	5.7	7.4	NAp	100

NAp Not applicable.
[1]Arkansas, Indiana, Iowa, Maryland, Montana, New Mexico, Oklahoma, and Wyoming.

Table 2.—Total underground coal production[1] stratified by State and mine size (number of employees) in 1989-91

State	Number of employees					
	1 to 20	21 to 50	51 to 100	Over 100	Total	% of U.S. total
Alabama	0.06	0.01	0.33	43.44	43.83	4.0
Colorado	0.76	2.03	4.44	17.70	24.92	2.3
Illinois	0.06	1.88	4.04	109.75	115.70	10.5
Kentucky	37.30	79.89	41.71	108.98	267.88	24.4
Ohio	0.93	1.71	0.23	29.75	32.61	3.0
Pennsylvania	3.57	9.24	13.09	85.26	111.16	10.1
Tennessee	2.56	4.37	2.62	1.54	11.09	1.0
Utah	1.62	0.69	10.24	45.60	58.16	5.3
Virginia	18.34	30.51	15.49	33.82	98.16	8.9
West Virginia	27.98	90.85	24.57	176.35	319.74	29.1
Other[2]	0.16	0.78	4.40	10.23	15.58	1.4
U.S. total	93.37	221.94	121.14	662.38	1,098.83	NAp
% of U.S. total	8.5	20.2	11.0	60.3	NAp	100.0

NAp Not applicable.
[1]Production is in millions of metric tons. To convert to short tons, multiply by 1.10232.
[2]Arkansas, Indiana, Iowa, Maryland, Montana, New Mexico, Oklahoma, and Wyoming.

CHANGES IN PRODUCTION, EMPLOYMENT, AND INJURY RATES DURING THE 1980's

Table 3 presents eight different measures of the U.S. underground coal mining industry stratified by mine size. To be able to see how the industry changed during the 1980's, statistics are presented that reflect two different periods: 1978-80 and 1989-91. Also included in the table is the percentage of change over the intervening 8-year span for each of the mine characteristics listed.

1978-80 Statistics

Several trends relating to mine size are evident for the period 1978-80. As mine size increases, the number of mines within each size category decreases and the number of employee-hours and the amount of production increases. The productivity rate, however, decreases with increasing mine size from 1.69 t/h at very small mines to 0.98 t/h at mines with 50 or more employees. Both the fatality rate and the permanent disability rate decrease with increasing mine size. However, the decrease in permanent disability rates (from 0.205 to 0.165 injuries per 200,000 h) is of a much lower magnitude than the decrease in fatality rates (from 0.245 to 0.062).

1989-91 Statistics

Trends similar to those observed for 1978-80 are evident for this period as well with one notable exception. The productivity rate is now highest for mines with 21 to 50 employees (2.69 t/h), followed by a productivity rate of 2.46 t/h for mines with 50 or more employees. It is the very small mines that now have the lowest productivity rate, 2.27 t/h.

1978-80 Versus 1989-91 Statistics

The last three columns in table 3 summarize the data aggregated across mine size for the two time periods and show the percentage of change from one time period to the next.

Productivity.—The most significant change is a 136% increase in overall productivity. This reflects a 42% increase in overall production and a 40% decrease in the overall number of employee-hours. Looking across mine size categories, the increase in production rate becomes more dramatic with increasing mine size, such that for mines with more than 50 employees the production rate has increased by 152%.

Number of Mines and Amount of Production.—The total number of mines in operation decreased by 32%. The

largest decrease (51%) was sustained by mines with 50 or more employees. Although the number of very small mines decreased by 39%, this category still constitutes over half (56%) of the total number of mines in operation. Conversely, the number of mines with 21 to 50 employees has increased by 8% from 631 mines in 1978-80 to 683 mines in operation during 1989-91. Similarly, this mine size category, in contrast to the larger and smaller mine sizes, shows a substantial increase in total production and number of employee-hours. Production at mines with 21 to 50 employees has increased 155% compared with an increase of only 21% and 29% for very small and large mines, respectively.

Fatalities and Disabling Injuries.—During the 1980's, the overall fatality rate decreased by 26%. The percentage of decrease in fatality rates becomes more pronounced with increasing mine size. For mines with more than 50 employees, the fatality rate has been decreased by almost half (43%). For very small mines, the fatality rate has decreased by 29%. Conversely, the permanent disability rate increased for all three mine size categories during the 1980's. The increases ranged from 11% for the smallest mines to 30% for mines in the 21- to 50-employee category. Overall, the increase was 20%. This increase is somewhat unexpected, and the reasons for it are not clear.

ACCIDENT TYPES

Fatal Accidents[4]

Table 4 breaks down the total number of accidents that resulted in one or more fatalities during the period 1987-91 by type of accident and mine size. Because fatalities are a relatively rare event, a 5-year span was used for this table rather than a 3-year span. Increasing the number of incidents under consideration helps to minimize the impact of annual fluctuations. Overall, ground fall accidents constituted close to half (46.7%) of the total number of fatal accidents occurring over this 5-year period. The majority (72%) of the 85 fatal ground fall accidents occurred in mines with 50 or fewer employees. [See Randolph (*7*) for an analysis of how ground fall accident rates vary according to mine size and various other factors. For some ideas about how to prevent roof fall accidents at small mines, see USBM Information Circular 9332 (*10*).]

[4]It is important to note that the accident statistics in tables 4 and 5 do not reflect fatalities experienced by independent contractors. If independent contractor fatalities were included, the trends might appear different. For example, powered haulage accidents are one of the most common causes of fatalities to independent contractors, but ground falls are not.

Table 3.—Number of operations, employee hours, production, and rates of fatalities and permanently disabling injuries during two 3-year periods stratified by mine size (number of employees)

	Number of employees											
	1 to 20			21 to 50			Over 50			Total or overall rate		
	1978-80	1989-91	% change	1978-80	1989-91	% change	1978-80	1989-91	% change	1978-80	1989-91	% change
Number of operations	1,995	1,217	-39	631	683	+8	585	287	-51	3,211	2,187	-32
Employee-hours[1]	45.76	41.20	-10	64.80	82.38	+27	622.23	318.85	-49	732.79	442.43	-40
Production[2]	77.09	93.37	+21	87.18	221.94	+155	607.32	783.51	+29	771.58	1,098.82	+42
Productivity[3]	1.69	2.27	+35	1.34	2.69	+100	0.98	2.46	+152	1.05	2.49	+136
Fatalities	56	36	-36	48	40	-17	193	56	-71	297	132	-56
Fatality rate[4]	0.245	0.175	-29	0.148	0.097	-34	0.062	0.035	-43	0.081	0.060	-26
Permanent disabilities[5]	47	47	0	55	91	+65	512	305	-40	614	443	-28
Permanent disability rate[4]	0.205	0.228	+11	0.170	0.221	+30	0.165	0.191	+16	0.168	0.200	+20

[1]Employee-hours are in millions of hours.

[2]Production is in millions of metric tons. To convert to short tons, multiply by 1.10232.

[3]Number of metric tons per employee-hour.

[4]Per 200,000 employee-hours of exposure.

[5]Includes all total and partial permanently disabling injuries except inguinal hernias that are repaired and losses of teeth or the tips of toes and fingers.

Table 4.—Number of accidents resulting in one or more fatalities at an underground coal mine stratified by type of accident and mine size (number of employees) in 1987-91

Accident type	Number of employees					
	1 to 20	21 to 50	51 to 100	Over 100	Total	% of total
Ground fall	33	28	6	18	85	46.7
Powered haulage	7	11	5	14	37	20.3
Machinery	1	7	4	11	23	12.6
Electrical	5	3	3	6	17	9.3
Explosives	3	1	1	0	5	2.7
Other	5	4	0	6	15	8.2
Total	54	54	19	55	182	NAp
% of total	29.7	29.7	10.4	30.2	NAp	100

NAp Not applicable.

The next most frequent type of fatal mining accidents are those associated with powered haulage equipment. MSHA's accident classification scheme considers powered haulage accidents to be those that are ". . . caused by the motion of the haulage unit, e.g., motors and rail cars, conveyors, shuttle cars, haulage trucks, front-end loaders, etc. Also includes any accidents caused by a moving part of the haulage unit." Fatal powered haulage accidents are almost evenly split between mines with over 50 employees versus mines with 50 or fewer employees. Further statistics on powered haulage accidents may be found in the Holmes Safety Association Bulletin (*4*).

Of the 182 accidents causing 1 or more fatalities, 54 occurred at mines with 1 to 20 employees, another 54 occurred at mines with 21 to 50 employees, 19 occurred at mines with 51 to 100 employees, and 55 occurred at mines employing over 100 people. Thus, a sizeable number of fatal accidents have occurred at *both* large and small underground coal mines.

It is interesting to note that the NAS (*5*) researchers found that the distribution of types of accidents causing fatalities did NOT vary much across mine size. They conclude that—

> This indicates that the larger fatality rate in small mines is not the result of an increase in a specific type of accident (e.g., roof falls). Rather, the data indicated that smaller mines are more likely than larger mines to have fatalities from each of the major types of accidents. This would suggest that the problem in small mines is not isolated to a specific work activity (such as roof bolting), but is present in all aspects of the mining effort.

Based on analysis of more recent data, this conclusion no longer appears true. Table 5 shows rates of fatal accidents stratified by accident type and mine size during 1987-91. In comparing the rate of various types of accidents at mines of 20 or fewer employees versus mines of 50 and over, one sees that the rate of fatalities is greater at very small mines for each major accident type (except machinery). This is in line with what the NAS researchers found. However, looking down the last column of table 5, one sees that the magnitude of the difference between rates of various types of fatal accidents at very small versus large mines varies quite a bit from one type of accident to the next. In particular, the rate of fatal ground fall accidents is 10.7 times greater at very small mines than it is at mines with over 50 employees. The corresponding ratios for fatal powered haulage, machinery, and electrical accidents are 2.9, 0.5, and 4.4, respectively. Thus, there is a much bigger disparity between fatal ground fall accident rates at very small versus large mines than there is for rates of other types of fatal accidents.

Table 5.—Rates[1] of fatal accidents stratified by accident type and mine size (number of employees) in 1987-91

Accident type	Mine size			
	1 to 20	21 to 50	Over 50	Ratio[2]
Ground fall	0.0965	0.0418	0.0089	10.8
Electrical	0.0146	0.0045	0.0033	4.4
Machinery	0.0029	0.0104	0.0056	0.5
Powered haulage	0.0205	0.0164	0.0071	2.9

[1]Per 200,000 employee-hours of exposure.
[2]Ratio of rate for 1 to 20 employees to rate of over 50 employees.

Serious Injuries

Table 6 breaks down the total number of serious injuries during 1989-91 by type of accident and mine size. In this table, serious injuries are considered to be any nonfatal injury that caused a permanent disability or that resulted in more than 20 days of lost work. The last two columns in table 6 list the numbers and rates of the various types of accidents that were reported by all the mines over this 3-year period. Overall, "handling material" accidents occurred at the highest rate (1.97), accounting for 36.4% of all serious injuries. The next highest rate was for "slip or fall" accidents (0.89), which accounted for 16.4% of all serious injuries. Together, these two accident types accounted for over half of the serious injuries reported over this 3-year period. For some ideas about how to prevent handling material accidents in coal mines, see Unger (*9*), Gallagher (*2*), Conway (*1*), and Hamrick (*3*).

A few trends are evident when looking at variations in the rate of specific types of accidents across mine size categories. It appears that rates of serious handling material accidents increase as mines get bigger. The rate of handling material accidents ranges from 1.42 at very small mines to 2.05 for mines with over 100 employees. Whereas handling material accidents account for 28% of all serious injuries at very small mines, they account for 38% of all serious injuries at mines of over 100 employees. Similarly, the trend is for serious injuries caused by slips or falls to occur at a higher rate as mine size increases. At mines of over 100 employees, the rate is over twice as high as at very small mines (1.11 versus 0.47).

Table 6.—Number and rates[1] of serious injuries[2] stratified by accident type and mine size (number of employees) in 1989-91

Accident type	Number of employees									
	1 to 20		21 to 50		51 to 100		Over 100		Total	Overall rate
	Injuries	Rate	Injuries	Rate	Injuries	Rate	Injuries	Rate		
Handling material	292	1.42	805	1.95	478	2.03	2,787	2.05	4,362	1.97
Slip or fall	96	0.47	230	0.56	140	0.60	1,502	1.11	1,968	0.89
Machinery	211	1.02	422	1.02	207	0.88	782	0.58	1,622	0.73
Powered haulage	227	1.10	427	1.04	178	0.76	746	0.55	1,578	0.71
Ground fall	97	0.47	220	0.53	92	0.39	493	0.36	902	0.41
Hand tool	51	0.25	91	0.22	64	0.27	462	0.34	668	0.30
Stepping or kneeling	20	0.10	49	0.12	28	0.12	153	0.11	250	0.11
Striking or bumping	7	0.03	10	0.02	5	0.02	132	0.10	154	0.07
Electrical	9	0.04	30	0.07	14	0.06	43	0.03	96	0.04
Other[2]	29	0.14	53	0.13	38	0.16	271	0.20	391	0.18
Total	1,039	5.04	2,337	5.67	1,244	5.29	7,371	5.42	11,991	5.42

[1]Per 200,000 employee-hours of exposure.

[2]Serious injuries include those classified as permanently disabling and those that caused the employee to miss more than 20 days of work.

Machinery accidents are the third most common type of accident resulting in serious injuries. They account for 13.5% of the total and occur at a rate of 0.73. Powered haulage accidents, with a rate of 0.71, account for 13.2% of the serious injuries reported by underground coal mines. In contrast to the previously noted trends across mine size categories, the trend is for serious powered haulage and machinery accidents to occur at successively lower rates as mine size increases. From the smallest to the largest mine size category, the rates for both categories of accidents decrease by about half.

Other differences relative to mine size include a slight decrease in the rate of serious ground fall accidents with increasing mine size (from 0.47 to 0.36), and a slight increase in the rate of serious hand tool accidents with increasing mine size (from 0.25 to 0.34).

FATALITY AND INJURY RATES FOR SELECTED STATES

Table 7 displays rates of fatalities, permanent disabilities, and serious injuries (injuries resulting in more than 20 lost workdays), stratified by State and mine size for 1989-91. The table is limited to only those States with at least 50 very small underground mines. The "overall" rates listed at the bottom of the table, however, include fatalities and injuries in underground coal mines from all States. Data are not given for Tennessee mines in the two largest size categories because of the extremely small number of large mines in Tennessee.

Fatality Rates.—As noted previously, looking across mine size categories, the overall fatality rate is highest for mines with 20 or fewer employees, then drops suddenly by almost half for mines with 21 to 50 employees, and drops by half again for mines with more than 50 employees. For the most part, this trend of decreasing fatality rates with increasing mine size is evident within each of the five States. The major exception to this overall pattern occurs in Virginia where the fatality rate for mines with 21 to 50 employees is slightly higher than that for the smaller mines. The last column in table 7 shows the overall fatality rates for each of the five States. They range from 0.015 for Pennsylvania to 0.114 for Kentucky. Of the five States, West Virginia and Kentucky have the highest fatality rates for very small mines, 0.223 and 0.180, respectively. It is interesting that these also happen to be the two States with the largest number of small mines.

Permanent Disability Rates.—The trends observed in fatality rates relative to mine size are not as clear and pronounced in the permanent disability rates. For example, although the overall fatality rate for very small mines (0.175) is five times as great as the fatality rate for very large mines (0.033), the overall permanent disability rate for very small mines (0.228) is only 1.2 times as great as that for the largest mines (0.183). Mines in the 51- to 100-employee category actually have the highest overall rate of permanent disabilities (0.238).

Serious Injury Rates.—Again, the clear trend that was observed in fatality rates relative to mine size is not present in the overall serious injury rates. The overall serious injury rates for very small mines (4.82) is actually less than that for the largest mines (5.24).

Other Trends.—Looking down the last column at the overall rates across States, one sees that the three measures of safety for Pennsylvania mines lead to conflicting conclusions. Although Pennsylvania had the lowest fatality rate among the five States, it had the second highest permanent disability rate (0.236) and the highest serious injury rate (6.81).

Looking across mine size categories within States, a few trends are apparent. In Pennsylvania, both the permanent disability and serious injury rates increase with increasing mine size, a twofold to threefold increase from the smallest to the largest mine size category. Conversely,

in Virginia, the serious injury rate decreases with increasing mine size, from 6.43 to 5.03, a 22% decrease from the smallest to the largest mine sizes.

Table 7.—Rates[1] of fatalities, permanent disabilities, and serious injuries[2] stratified by State and mine size (number of employees) in 1989-91

State and rate	Number of employees				
	1 to 20	21 to 50	51 to 100	Over 100	Overall rate
Kentucky:					
Fatality	0.180	0.100	0.094	0.105	0.114
Permanent disability	0.252	0.288	0.216	0.177	0.227
Serious injury	4.36	5.36	4.97	4.50	4.79
Pennsylvania:					
Fatality	0.156	0.000	0.000	0.010	0.015
Permanent disability	0.078	0.155	0.199	0.259	0.236
Serious injury	3.05	4.82	6.46	7.30	6.81
Tennessee:					
Fatality	0.112	0.073	Neg.	Neg.	0.058
Permanent disability	0.224	0.366	Neg.	Neg.	0.259
Serious injury	4.60	4.46	Neg.	Neg.	3.97
Virginia:					
Fatality	0.122	0.166	0.050	0.013	0.084
Permanent disability	0.171	0.181	0.250	0.139	0.177
Serious injury	6.43	5.89	5.85	5.03	5.68
West Virginia:					
Fatality	0.223	0.066	0.021	0.015	0.047
Permanent disability	0.241	0.173	0.338	0.146	0.176
Serious injury	4.88	5.65	5.04	4.66	4.96
Total:					
Fatality	0.175	0.097	0.047	0.033	0.060
Permanent disability	0.228	0.221	0.238	0.183	0.200
Serious injury	4.82	5.45	5.05	5.24	5.22

Neg. Negligible. Data are not reported because the number of mining operations in this category was extremely small.

[1]Per 200,000 employee-hours of exposure.

[2]Injuries, other than those classified as permanently disabling, which caused the employee to miss more than 20 days of work.

EMPLOYEE-HOURS AND PRODUCTIVITY

Table 8 displays total employee-hours and productivity during 1989-91 for each of the five States where the majority of small mines are located, broken down by mine size. Across the five States, productivity ranges from 1.60 t/h for Tennessee to 2.69 t/h for West Virginia. Across the different categories of mine size, productivity ranges from 2.27 t/h for very small mines to 2.69 t/h for mines with 21 to 50 employees.

CHARACTERISTICS OF SERIOUSLY INJURED MINERS

Table 9 displays the mean age of seriously injured miners during 1989-91, as well as the number of years of experience they had (1) working at their current mine, (2) working in their current job classification, and (3) working as a coal miner. The overall means as well as the means for four mine size categories are presented. The means for each of the four victim characteristics steadily increases as mine size increases. The mean for "experience at mine" displays the most dramatic increase, from 1.95 for very small mines to 11.0 for mines with over 100 employees. This may largely reflect the fact that most small mines do not remain open for nearly as long as large mines. It may also reflect a tendency for younger, less experienced miners to be hired by small mines rather than large mines, and that when larger mines have had to lay off workers during the 1980's, it was the younger miners who lost their jobs.

Table 8.—Total employee hours[1] and productivity[2] stratified by State and by mine size (number of employees) in 1989-91

State and variable	Number of employees				
	1 to 20	21 to 50	51 to 100	Over 100	Total or overall rate
Kentucky:					
Employee-hours	16.646	29.876	14.835	41.926	103.282
Productivity	2.24	2.68	2.81	2.60	2.59
Pennsylvania:					
Employee-hours	2.557	3.860	6.041	39.344	51.803
Productivity	1.40	2.39	2.17	2.17	2.15
Tennessee:					
Employee-hours	1.782	2.734	1.254	1.177	6.946
Productivity	1.43	1.60	Neg.	Neg.	1.60
Virginia:					
Employee-hours	8.211	13.274	8.006	15.826	45.317
Productivity	2.23	2.30	1.93	2.14	2.17
West Virginia:					
Employee-hours	10.787	30.113	9.479	68.617	118.996
Productivity	2.59	3.02	2.59	2.56	2.69
Total or overall rate:					
Employee-hours	41.203	82.383	47.025	271.820	442.431
Productivity	2.27	2.69	2.58	2.44	2.49

Neg. Negligible. Data are not reported because the number of mining operations in this category was extremely small.

[1]Hours are in millions.

[2]Number of metric tons per employee-hour.

Table 9.—Mean age and experience of seriously injured[1] miners stratified by mine size (number of employees) in 1989-91

Victim characteristic	Number of employees				
	1 to 20	21 to 50	51 to 100	Over 100	Overall
Age	32.3	34.0	36.7	40.3	38.0
Experience at mine	1.95	2.6	5.3	11.0	8.0
Experience in job	5.6	5.8	6.0	6.7	6.1
Total mining experience	12.1	13.0	13.4	14.9	14.2

[1]Serious injuries include those classified as permanently disabling and those that caused the employee to miss more than 20 days of work.

It is interesting to note that the age distribution of miners at various sizes of mines appears to have changed since the NAS (*6*) study was conducted. The NAS researchers reported finding no age differences relative to mine size. However, the present data show a difference of 8 years between the average age of injured miners at small mines (32.3) versus large mines (40.3). (A note of caution: One must keep in mind that the ages of injured miners may not necessarily correspond to the ages of all miners in the work force.)

MINE-LEVEL DESCRIPTIVE STATISTICS

Data on mining accidents, employment, and production can be aggregated or grouped at various levels of analysis. Throughout the tables of statistics discussed thus far, the data have NOT been based on mine-level analyses. The data from all mines that fell within a specified size category were aggregated or pooled together in the calculation of statistics. For instance, accident rates have been calculated by adding together all the accidents that occurred throughout all the mines in a particular size category, dividing this number by the sum of all the employee-hours worked throughout those same mines and then multiplying by 200,000.

However, in table 10 the statistics are based on data aggregated at the mine level of analysis. In this procedure, the first step is to calculate an accident rate for each mine. The mean accident rate for mines in a particular size category is then computed by finding the average of the rates for each of the mines in that size category. An important feature of using the mine level of analysis is that each mine is treated as a single data point and given the same weight as any other mine. An advantage of this procedure is that it allows one to see the variation that exists among the mines in a particular size category. Table 10 presents mine-level descriptive statistics for productivity, seam height, and rate of serious and fatal accidents during 1989-91.

Productivity.—Statistics are reported for all underground coal mines as well as for each of four mine size categories. The differences in the figures for mean mine-level productivity between different mine size categories correspond fairly closely to what was reported in table 3. The smallest mines have the lowest mean productivity rate (2.07), and mines in the 21- to 50-employee category have the highest productivity (2.66).

Seam Height.—As was reported in the NAS (*5*) study, there is still a clear trend toward larger mines operating in higher coal seams. The overall median seam height is 109 cm (43 in). The median for the category of very small mines is 102 cm (40 in). As mine size increases, the median seam height steadily increases, such that mines with over 100 employees have a median seam height of 168 cm (66 in).

Rate of Fatalities and Serious Injuries.—Looking at the mean and median rate of fatalities and serious injuries across mine size categories, there appear to be no clear trends. However, the standard deviations (std dev) show a decreasing trend with increasing mine size. The difference between the largest mines (std dev = 3.16) and the smallest mines (std dev = 17.10) is particularly dramatic and is further reflected in the differences between the medians for these two categories. The median of 0.00 for mines with 20 or fewer employees indicates that at least 50% of the mines in this size category reported zero serious injuries or fatalities for the period 1989-91 even though the average number of such incidents reported for these small mines is almost 6.

In contrast, for mines with more than 100 employees, at least 50% of these mines reported almost 5 fatalities or serious injuries and the average number reported is 5.71. With regard to this particular characteristic, smaller mines look very different from one another relative to the homogeneity exhibited by larger mines.

Table 10.—Mine-level descriptive statistics for productivity, seam height, and rate of fatalities and serious injuries[1] stratified by mine size (number of employees) in 1989-91

Mine characteristic and rate	Number of employees				
	1 to 20	21 to 50	51 to 100	Over 100	Overall
Productivity:[2]					
Median	1.92	2.46	2.54	2.30	2.15
Mean	2.07	2.66	2.60	2.49	2.31
Std dev	1.34	1.24	1.05	1.07	1.31
Seam height:[3]					
Median	102	117	135	168	109
	(40)	(46)	(53)	(66)	(43)
Mean	112	127	145	180	124
	(44)	(50)	(57)	(71)	(49)
Std dev	43	46	46	53	51
	(17)	(18)	(18)	(21)	(20)
Rate of fatalities and serious injuries:[4]					
Median	0.00	4.82	4.69	4.92	3.21
Mean	5.57	6.20	5.25	5.71	5.76
Std dev	17.10	6.30	3.24	3.16	13.28

Std dev Standard deviation.

[1]Serious injuries include those classified as permanently disabling and those that caused the employee to miss more than 20 days of work.

[2]Number of metric tons per employee-hour.

[3]Centimeters (numbers in parentheses are in inches). The U.S. mining industry refers to seam height in terms of inches.

[4]Per 200,000 employee-hours of exposure.

SUMMARY AND CONCLUSIONS

It was found that fatality rates decline substantially as mine size increases. The fatality rate is 0.175 deaths per 200,000 h for mines with 20 or fewer employees. The rate drops by almost half for mines with 21 to 50 employees, and drops by half again for mines with more than 50 employees. Likewise, rates of permanently disabling injuries decline as mine size increases. However, there is no clear-cut trend in the relationship of mine size to the rate of other types of serious accidents—ones that cause the employee to miss more than 20 days of work. The rate of serious accidents is lowest for mines that employ 1 to 20 employees, highest among mines that employ 21 to 50 people, and intermediate for mines that employ more than 50 people.

Fatality rates are currently substantially lower than they were in the late 1970's. Although fatality rates decreased during the 1980's for each mine size category, the percentage of decrease was lowest among the smallest size mines and highest among the largest size mines. In looking at the differences between rates of various types of fatal accidents at small versus large mines, it appears that ground fall accidents are a particularly important problem for small mines. The rate of fatal ground fall accidents is over 10 times greater at mines with 20 or fewer employees than it is at mines with over 50 employees.

Several trends become evident when looking at differences in the rates of specific categories of serious accidents across mine size categories (see table 6). In particular, the rates of accidents classified as "handling materials" and "slips or falls" increase with increasing mine size. Conversely, rates for accidents classified as "machinery" and "powered haulage" decrease with increasing mine size.

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Proceedings: Bureau of Mines Technology Transfer Seminar

Compiled by Robert H. Peters

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